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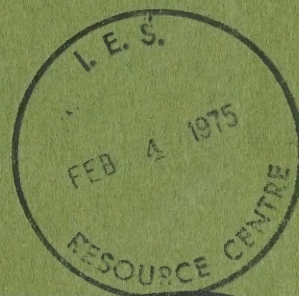
THE ROLE OF FIRE IN THE BOREAL FOREST OF CANADA. /
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CHALK RIVER, ONTARIO
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OF CANADA

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ABSTRACT

Through a review of literature, the essential role of fire in the boreal forest as a natural regulatory agent of composition and succession is discussed in terms of plants, soils, and animals. In natural, long-term cycles, the incidence of lightning-started fires on a particular area may have been only once in one to three centuries, but fire nevertheless has always been an agent for destruction and renewal of boreal forest stands.

It is suggested that fire's beneficial effects, e.g. nutrient cycling, removal of excessive mor humus, warming of soil surface, depression of permafrost, provision of browse, etc. should be utilized in managing the forest's renewable resources. Research on physical, physiological, and ecological effects of fire will supplement the meagre experience available for effective management of the boreal forest.

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THE ROLE OF FIRE IN THE BOREAL FOREST
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by
A.J. Kayll^{1/}

INTRODUCTION

In any discussion of fire related to natural communities of plants and animals, it is very difficult to divorce sentiment and emotion from fact. "Bambi" and "Smokey Bear" have been all too effective and a lack of objectivity may spill over into scientific writing. An article on caribou in northern Canada in the May 4 issue of the New Scientist (Hillaby, 1968) illustrates this point:

"...Fire is one of the oldest, most insidiously destructive forms of land change, wiping out all but the most resilient, rank, and enveloping forms of vegetation. Fire was largely responsible for the destruction of the Scottish highlands. In combination with over-grazing it has turned the Southern Pennine moors into bare hags of dissected peat..."

Such an emotionally charged discourse is most difficult to combat with scientific and perhaps somewhat matter-of-fact prose. But it nevertheless remains that not all fire in the forest is bad; that not all effects of fire are detrimental; that not all fires were holocausts which led to "...rank and enveloping forms of vegetation..." occupying potentially productive sites. This does not mean that fire is not destructive in terms of man's utilization,

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but rather that in a natural, long-term cycle, fire can be simultaneously the terminating and regenerating agent of the forest.

The role of fire in the boreal forest is one of disturbance, regulation, and cycling. Disturbance in that fire may be the keystone of stand origin and development; regulation in that fire may determine composition and direct succession; and cycling in that otherwise immobile nutrients may be moved in a cold and sluggish ecosystem. So powerful an agent, if uncontrolled, can have far-reaching effects for both good and bad. On the assumption that the disastrous consequences of fire are generally well known, this paper relates mostly to its benefits.

This paper is confined to a limited treatment of fire's occurrence in the boreal forest in Canada, its effects on components of the forest, and suggestions for its application and use. A bibliography of selected titles is included.

FIRE AS AN ECOLOGICAL AGENT

The relationships of forests and forest fires were discussed by Pinchot as early as 1899. Since then, in addition to the general review of ecological effects of forest fires by Ahlgren and Ahlgren (1960), fire has been discussed or mentioned as an ecological agent in the boreal forest as a whole (La Roi, 1967; Rowe, 1959), in the forests of central Newfoundland (Damman, 1964), Labrador (Hustich, 1951; Wilton, 1964), in northern and northwestern Alberta (Raup, 1946; Moss, 1953), in Alaska (Lutz 1956, 1959, 1960) and in northern Sweden (Uggla, 1958b) as well as many other locations.

Occurrence

There can be little doubt that fire has always been a feature of the boreal forest. Bennett's (1960) maps show almost 10,000 lightning fire

occurrences plotted for the years 1950 to 1959 for Canada's forests. These were the observed occurrences in "protected" forests, i.e. forests with organized fire-fighting crews. Kourtz (1967) tallied 3,615 lightning-caused fires in the years 1960 to 1963. He estimates 20 percent of all Canadian forest fires are started by lightning, and McLean and Lockman (1967) estimate 27 percent. Hardy and Franks (1963) indicate that 25 percent of forest fires in Alaska are started by lightning, and incidentally account for 75 percent of the area burnt.

According to Rowe (1961), ... "The western boreal forest is a disturbance forest usually maintained in youth and health by frequent fires to which all species, with the probable exception of fir, are nicely adapted..."

Uggla (1958a) states that in Sweden: "...Fire has always been a very important factor in determining the extent and composition of boreal forests...", and Shostakovitch (1925) indicates a similar situation in Siberian forests, although he emphasizes man-caused rather than lightning-caused fires.

The likelihood of naturally-caused fire on any given area is low, perhaps in the order of once in one to three centuries. With a low frequency, even severe devastating fires probably could be tolerated in the unexploited forest. But in terms of utilization demands by modern man, such destruction cannot be tolerated. The periodicity reported by MacLean and Bedell (1955) for the Northern Clay Belt of Ontario of at least once in the past 130 or 140 years, and a high fire frequency at about 30-year intervals, further aggravates possible adverse effects.

In evaluating the effects of fire, not only must its presence and frequency be noted, but also its type (Jeffrey, 1961) e.g. a light ground or an intense crown fire. Consideration must also be given to the various physiological,

ecological, and morphological features of the organisms being subjected to fire. The major components of the boreal forest are discussed in relation to fire in the following paragraphs.

Effects on Trees

Black spruce (Picea mariana [Mill.] BSP.) is well adapted to fire for survival of the species, if not the individual. Its cones are semi-serotinous and are generally opened by heat. Horton and Lees (1961) found slightly scorched semi-open cones contained viable seed and Lutz (1956) found the seed supply contained in crowns was seldom completely consumed, even in severe crown fires. Black spruce will germinate well on exposed mineral soil (Jarvis, 1966), and both Wilton (1964) in Labrador and Horton and Lees (1961) in Alberta found establishment of black spruce over the whole range of sites could be traced to fire origin. Hatcher (1963) noted high volumes and rapid growth in fire-origin stands of black spruce, indicating perhaps a rejuvenating effect of fire. Damman (1964) adds a note of caution by saying young stands bearing no cones cannot regenerate after fire, and that "...repeated fires will...eventually reduce almost any forest into wasteland..."

White spruce (P. glauca [Moench] Voss) is not particularly fire resistant, but does germinate well on exposed mineral soil (Bedell, 1948; Jarvis, 1966; Lutz, 1956). Following fire, regeneration probably develops from adjacent, unburned stands (Lutz, 1956). In Labrador, white spruce is a minor constituent in the undisturbed forest on good sites (Wilton, 1964), but in western Canada, the evidence of burning is very clear (Jeffrey, 1964) and white spruce prevalent.

Balsam fir, (Abies balsamea [L.] Mill.) with its thin bark is highly susceptible to fire (Bakuzis and Hansen, 1965) and is seldom found in fire-origin stands (Wilton, 1964). Damman (1964) reports balsam fir is strongly reduced or eliminated by fire and that the proximity of a black spruce seed source usually

determines fire succession in the balsam fir forest-type.

Jack pine (Pinus banksiana Lamb.) is the classical "fire species". The statement of Bedell, Brown and MacLean (1953)"... Fire is necessary for establishing the [jack pine] type, whether pure or mixed..." is supported by many authors, e.g. Ahlgren (1959b, 1960), Jarvis (1966), Cayford, Chrosciewicz, and Sims (1967). Jack pine requires heat (fire) to open its serotinous cones and a mineral seedbed to establish its seed.

Dansereau (1953) calls jack pine the most remarkable of the pines (in comparison with Pinus resinosa Ait. and P. strobus L.) in that its closed cones can survive fire. The cones require at least 140°F to open (Beaufait, 1960), and interestingly, Ahlgren (1959a) found seed from scorched cones germinated as much as 50 percent better than from unburned cones and also germinated earlier. Eyre (1938) found on an area burnt in May that the fall of seed began almost immediately after the fire and that within four days most had fallen. With favourable conditions, i.e. good mineral seedbed (Jarvis, 1966), adequate seed source, and adequate moisture (Cayford, 1963), excellent stocking can be expected.

Lodgepole pine (P. contorta Dougl. var. latifolia Engelm.) has characteristics similar to jack pine. Horton (1956) stresses fire as the primary historic factor determining forest composition and succession in the foothills of Alberta.

White birch (Betula papyrifera Marsh.) is a common pioneer species on burns (Damman, 1964; Wilton, 1964), its particular advantage being a light, readily disseminated seed. Lutz (1956) mentions an observation by Kujala of trees sufficiently burned to kill the cambium completely around the base. Those trees which retained a mantle of foliage yielded an excess of ripe seed. Lutz concludes: "...If this habit is general in birch, it must have an important

influence on reproduction following fires..."

Trembling aspen (Populus tremuloides Michx.) has seed well suited to widespread dissemination by wind (Lutz, 1956) and is a pioneer species on many burns (Wilton, 1964; Stoeckeler, 1948). But aspen suckering is stimulated by light to moderate burns (Shirley, 1931; Horton and Hopkins, 1965; Maini and Horton, 1966) and may be the main method of reproduction (Ahlgren, 1959b). Horton and Maini (1964) consider that fire would seldom be severe enough to weaken reproductive capacity.

Balsam poplar (P. balsamifera L.), with its thick bark and light, wind disseminated seed is well protected against and adapted to fire (Lutz, 1956), but the species usually only occupies recently deposited soils of river courses, etc. (Wilton, 1964).

Tamarack (Larix laricina [Du Roi] K. Koch) is, according to Wilton (1964), the hardiest of northern conifers and occurs in both undisturbed and fire-origin stands. Its presence in the boreal forest is minor and apparently has received little study in relation to fire.

Effects on Shrubs, Herbs, and Mosses

The aerial parts of shrubs are obviously consumed in fires, but the roots are often not damaged (Tucker and Jarvis, 1967; Smith and Sparling, 1966). Lutz (1956) mentions that as a group, shrubs have a remarkable capacity for vegetative regeneration through sprouts arising from stem bases and roots. Wind-borne seeds and those in unburned organic material supplement vegetative regeneration. Herbs can often regenerate vegetatively, but seed is probably more general and important. Mosses are generally consumed by fires, but the extent will

be modified by species and moisture. Reproduction is probably mostly vegetative (Lutz, 1956).

Effects on Soils

Burning of northern forests frees the nutrient capital, an otherwise frozen asset. According to several authors, (Gagnon, 1965; Lutz, 1956; Scotter, 1963; Weetman and Nykvist, 1963), chemical changes are ecologically favourable. Exchangeable calcium, potassium and phosphorus may be increased; pH decreased; total nitrogen decreased, but amount available increased; water infiltration rates not impaired; soil temperatures increased and the depth to permafrost consequently also increased. Tucker and Jarvis (1967) noted that: "Because of the high moisture content of the F and H horizons [at time of slash burning], reduction in the depth of the organic horizon was almost nil, even under the large slash piles." Uggle (1958a) states that condensation of water vapour formed in the burning of organic matter produces a "sweating zone" which effectively prevents the fire from penetrating deeply. However, burning on shallow soils can be followed by serious erosion and consequently cause a very prolonged period of recovery.

Effects on Animals

It has been generally thought that uncontrolled fire is detrimental to fur-bearing animals, but controlled fire may be beneficial. Ward (1968) has found this to be so for muskrats in Manitoba marshes. Ahlgren (1966) found burning creates habitats and food conditions favourable to the increase in populations of seed-eating mouse species in northeastern Minnesota, and this likely is the case for areas of the boreal forest. High mortality of animals in fires, although often mentioned, has not been documented, and at least one

authority^{2/} believes there is probably little.

The effect of fire on moose populations may be simply a case of "more browse - more moose" as on Isle Royale (Ahlgren and Ahlgren, 1960) because of other factors affecting big game habitat. However, fire does give rise to suitable stands of browse and the possibilities of prescribed burning for wildlife management in the boreal forest are recognized (Lutz, 1956).

For reindeer and caribou, destruction of lichens is disastrous. Recovery of lichens after fire is usually prolonged and may take 40 years or more (Hustich, 1951).

FIRE AS A SILVICULTURAL TOOL - ITS FUTURE ROLE

The foregoing has touched on the historic role of fire in the boreal forest and its effects on various components. It remains now to comment on the future role of fire in the boreal forest, i.e. the use of prescribed or controlled fire as a management tool of the forest's renewable resources. Foster (1967) outlined some uses of prescribed fire as follows:

- to prepare seedbeds by reducing humus and litter
- to open the serotinous cones of jack pine and black spruce for seed dispersal
- to cultivate blueberries
- to prepare barrier strips against large fires, and hazard-reduction generally
- to open the forest for game animals and stimulate growth of food plants
- to control insect infestations

^{2/} E. Komarek (Executive Secretary of Tall Timbers Research Station) in personal communication, 1968.

- to improve low-quality hardwood stands
- to provide training for fire fighters.

He also makes the point that there are overmature forests in Canada which are "silvicultural slums" partly because of fire control policies. If a mature forest cannot be harvested, then fire may be one way to establish a valuable new forest in its place.

Weetman (1956) twelve years ago considered prescribed burning a suitable technique for use in jack pine, white pine, black spruce swamp, and upland mixed-wood forest types. Gauvin's (1964) conclusion: "A thorough knowledge of the numerous factors affecting the regeneration and the evolution of forest after fire would tend toward the evolution of the regeneration of softwood stands by the application of certain efficient and low-cost treatments". Prescribed burning is probably one of these treatments. Dobbs (1967), Williams (1960), and others have found prescribed burning to be an effective tool in jack pine types in Manitoba, and Wagg (1964) suggests the technique as being worthwhile in regeneration silviculture in the white spruce forests on the Peace and Slave River lowlands. Bloomberg's (1950) comment 18 years ago is pertinent: "...It may not be too fantastic to consider the day when we shall wonder whether fire, in some form at least, has not been a friend masquerading as a foe..."

A closing speculation: with the advent of new, whole-tree harvesters which limb, top and cut black spruce trees at the rate of one per minute, would it be completely on the "lunatic fringe" to suggest a seed-releasing crown fire before harvesting begins? Perhaps not, but there are many unknowns yet to be described. Research on physical, physiological, and ecological effects of fire will supplement the meagre experience available for the effective management of the boreal forest.

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